The results obtained in these observations are thought to be only roughly comparable, since varying atmospheric and other conditions may affect the readings, such as wind movement, humidity, intensity of solar radiation, composition of coloring matter, etc.

DIURNAL PRESSURE CHANGE IN GULF OF FONSECA.

Capt. E. S. Jackson, commanding officer of the U. S. S. *Tacoma*, recently reported through the Hydrographic Office what he considered to be an instance of unusual diurnal pressure change. During the period from January 29 to February 29, 1920, while the *Tacoma* was stationed at Amalpa, Honduras, Gulf of Fonseca, Capt. Jackson observed daily between the hours of 12 noon and 1 p. m. a very sharp fall in the barograph trace. The average drop for an 8-day period, from January 29 to February 4, inclusive, during which the fall was most pronounced, was slightly more than 0.05 inch. There was no accompanying noticeable weather change.

Central America is on the northern edge of the area of greatest diurnal pressure variation in the Western Hemisphere, an area which, roughly, embraces Central America and the north-central portions of South America. As an example of the change that may occur in this region it is noted that at Mexico City the average diurnal fall in pressure from noon to 1 p. m. is about 0.04 inch.

The hourly rate of fall is, however, considerably less than that observed by Capt. Jackson for the hour 12–1 p. m., although the average total fall for all the afternoon hours is fully as much.

The barometric trace from the Weather Bureau station at Swan Island, off the northern coast of Honduras, the nearest point from which such a record is available, shows no unusual characteristics for the period in question.

Capt. Jackson has promised a further report to be made from La Union, Salvador, also in the Gulf of Fonseca.

THE CLIMATE OF JAPAN AND FORMOSA.

By ELLEN MARY SANDERS.[1]

The climate of the festoon of islands which begins in the south with Formosa near latitude 21° N., and stretches northward to Yezo near latitude 46° N., is exceptionally interesting, not only as illustrating the change of climate which naturally comes about with such a change of latitude, but because it presents so great a contrast to the other countries bordering the oceans lying in the same latitude. A large body of data is now available, since the Central Meteorological Observatory of Tokio has been at work for over thirty years observing and collecting the results of other observers, and the observatories of Formosa have been working for close upon twenty years, so that a more detailed description of the climate of Japan and Formosa is possible than has as yet been given. Such a description is the aim of the present article. It can only be regarded as tentative, liable to modification when further data are forthcoming.

No description of the climate of Japan would be complete which did not emphasize the influence of the continent of Asia. Therefore, at the risk of repeating what is already well known an introductory account of the general results of the position of the islands is included. This is followed by a consideration as to the effects of ocean currents, and an account of the storms to which the islands are subject, on both of which topics new material is available. After these general considerations a detailed description of the climatic zones is given, based on the reports of the observatories of Japan and Formosa.

General results of position.[2]—Japan is situated off the east coast of Asia, so that during the cold season it has an immense stretch of frozen land to windward, and as a result its temperature is far colder than is normal for its latitude. In addition to the modification in temperature the distribution of rainfall is also a result of the proximity of the great land mass.

In winter the central part of Asia becomes an area of high pressure since the land cools more quickly than the water, therefore the winds blow out from the center. Fig. 1 shows the winter winds of Japan and Formosa. Japan comes into the track of those winds which blow from the NW. coming across the cold lands of northern Asia. To these winds the north coast of Japan owes its rain, and the cold winter, particularly marked in the island of Yezo. Formosa, on the other hand, comes into the zone of the NE. Trade Winds during its cool season, and thus has winds coming over the ocean from a northeasterly direction.

In summer the central part of Asia becomes an area of low pressure, due to the heating of the land mass, and consequently winds blow in toward the center from all sides. Fig. 2 shows the direction of such of these winds as cross Japan. It will be noticed that they blow from the SE. and that they traverse the ocean before reaching Japan, thus they are warm, moisture-laden winds. To these winds the southern coast of Japan owes the greater part of its rain, while Formosa, which lies far enough to the south to get the full force of the Monsoon, shares with China one of the heaviest rainfalls of the entire globe.

Ocean currents.—It was formerly thought that the ocean currents which flow in the adjoining seas were one of the most important factors of the climate of Japan. Recent investigations have led to a modification of this view. Therefore it is necessary to examine the effects of the ocean currents on the climate.

There are two warm ocean currents, the Tsushima and the Kuroshio, and one cold current, the Oyashio. The warm current, called the Tsushima, enters the sea of Japan through the strait of Korea and touches the northwest coast of Nippon.[2] The curve of the isotherms on the west coast of Japan, which may be seen in Fig. 7, is perhaps due in part to this current, although, in the main, the relief is responsible for the course of the isotherms. A large amount of the fog and rain which comes to the west coast during the winter may also be due in part to this current, since in winter the prevailing wind comes straight from the part of the ocean which is warmed by it.

The cold current, called the Oyashio, flowing in a southwesterly direction, touches the eastern and southern coasts of Hakodate and also eastern Nippon, and may contribute toward lowering the temperature of these districts. The other warm current, the Kuroshio, which touches the southern coast of Nippon in its course toward the northeast, is far more powerful than either of the others, and higher in temperature than the Tsushima. The great amount of rain on the southeastern coast of Japan during the summer may be partly due to this current.

[1] B. A. London and Bristol, England: Docteur de l'Univ. de Paris, France; British scholar, Bryn Mawr, U. S. A.

[2] Atlas of Meteorology. Bartholomew and Herbertson, (a) Plate 14 Pressure.

[2] Art. 4, Vol. XXXVII, Journal of Coll. of Sc. Imperial Univ. of Tokio.

In the report of the Central Meteorological Observatory of Japan, issued in 1893, it is stated that the effect of the Kuroshio is far less than that of the other two currents, and that the current view as to the great effect it has upon the climate is incorrect. This conclusion is supported by the fact that in winter the average temperature of Japan is 10° F. colder than is normal for its latitude. This is in striking contrast to the state of affairs in the British Isles, where the average winter temperature is 30° F. warmer than is normal for its latitude and shows that the influence of the warm currents on the climate of Japan is not comparable to that of the Gulf Stream upon climate of the British Isles. The same report as is quoted above also emphasizes the effect of the two smaller currents, but the isoanomalous lines, as given in the Meteorological Atlas, hardly support this view.[3] It seems as if more detailed research work on the subject is necessary before any satisfactory conclusion can be drawn.

Storms.—Not only is the climate of Japan profoundly modified by the influence of the continent on the west and the ocean on the east, but the storms which sweep across it play their part. Fig. 15 shows that Japan receives a large number of cyclonic storms every year. The shading on the map shows the frequency of these storms during the years 1905–1915. The map is based on the daily weather maps issued by the Central Observatory of Tokio, which are by far the most detailed and accurate data yet available. When comparing it with maps which show the frequency of cyclonic storms in Europe it must be borne in mind that the areas into which the Japanese map is divided are 2½ degrees of latitude by 2½ degrees of longitude, while the more usual system is to divide the map into areas of 2½ degrees of latitude by 5 degrees of longitude. Allowing for this fact, it is apparent that Japan has not as many storms as western Europe or as the eastern part of the United States.[4] but that enough storms strike Japan to relieve the climate from the monotony which prevails in Formosa and in the countries which face Japan on the mainland of Asia.

In addition to the cyclones this festoon of islands is visited by typhoons. Formosa lies right in their track and the storms generally move toward the northwest or the west-northwest and sometimes curve around to the northeast, in which case they strike the southern part of Japan. Fig. 3 shows the course and frequency of these storms.[5]

Fig. 1

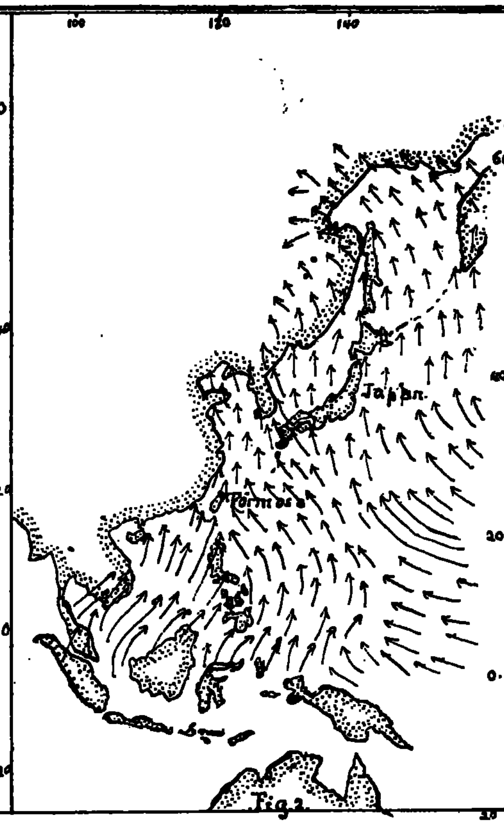

Fig. 2

Fig. 1 Ocean Winds during January and February. Barth. Phys. Atlas Pl. 14

Fig. 2. Ocean Winds during July and August. Bartholomew Phys. Atlas. Pl. 14.

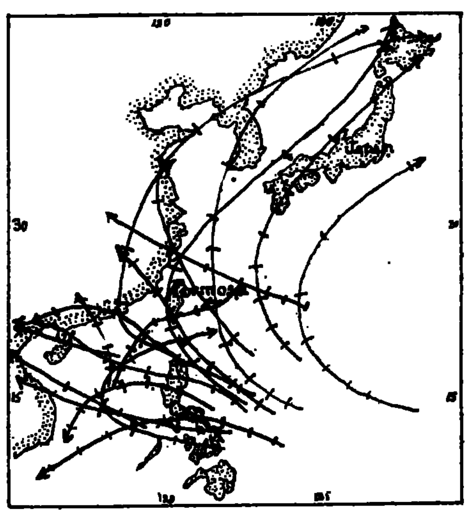

Fig. 3. Average Typhoon Tracks. By W. Doberck. Average rate of progress per 24 hours indicated by short cross lines.

[3] Atlas of Meteorology, Bartholomew and Herbertson, (c) Plate 2 Isanomalous lines.
[4] Bull. of the Geol. Soc. of America, Vol. 25, pp. 477-590, 1914.

[5] The Climate, Typhoons and Earthquakes of Formosa, Taihoku Meteorological Observatory, Taihoku, Formosa, 1914.

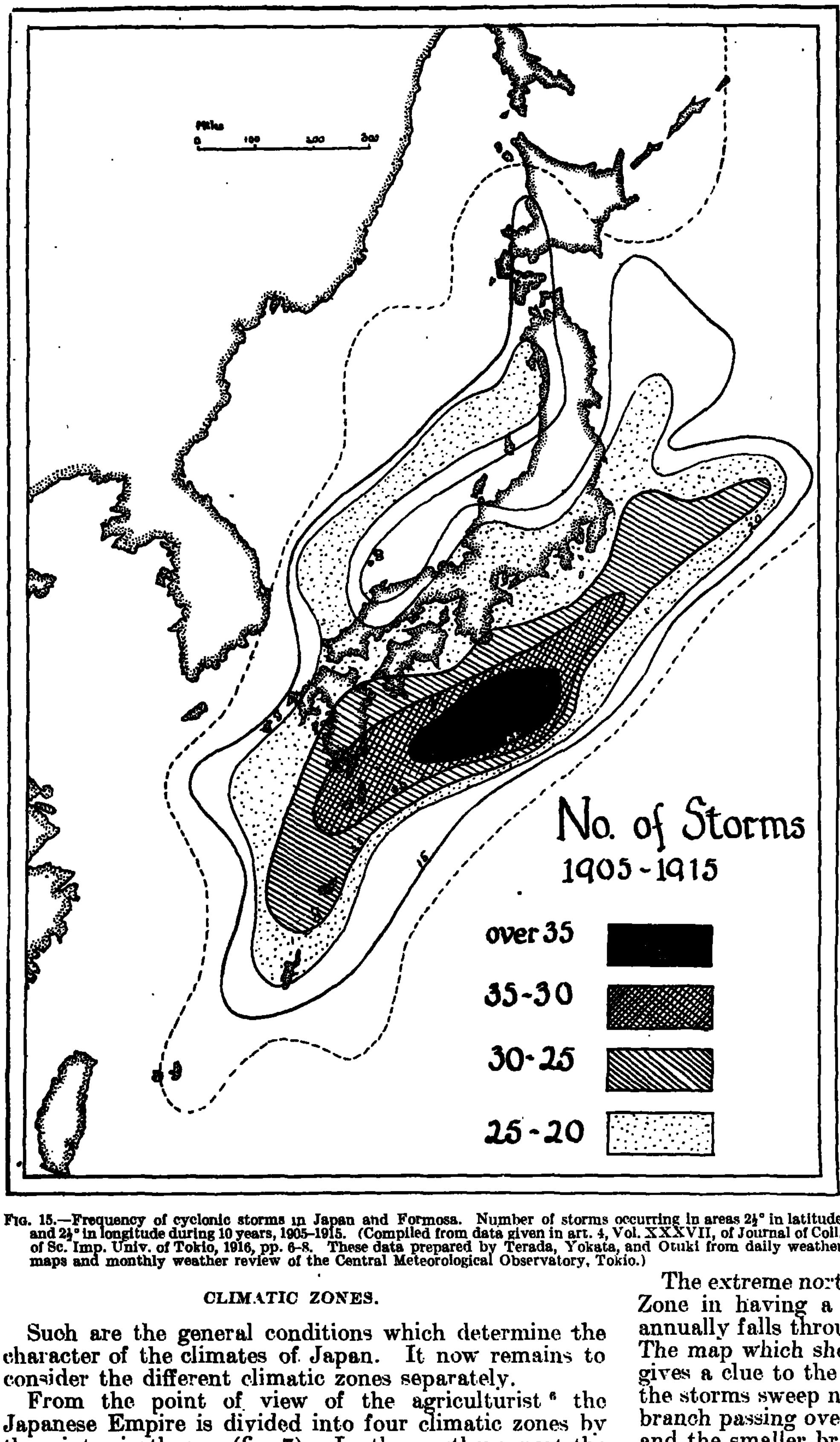

FIG. 15.—Frequency of cyclonic storms in Japan and Formosa. Number of storms occurring in areas 2½° in latitude and 2½° in longitude during 10 years, 1905–1915. (Compiled from data given in art. 4, Vol. XXXVII, of Journal of Coll. of Sc. Imp. Univ. of Tokio, 1916, pp. 6–8. These data prepared by Terada, Yokata, and Otuki from daily weather maps and monthly weather review of the Central Meteorological Observatory, Tokio.)

CLIMATIC ZONES.

Such are the general conditions which determine the character of the climates of Japan. It now remains to consider the different climatic zones separately.

From the point of view of the agriculturist [6] the Japanese Empire is divided into four climatic zones by the winter isotherms (fig. 7). In the northern part, the ground is frozen during the winter and only the summer is available for the crops, so that north of Jan. isotherm 32° F. can be marked off as the Northern Zone. As one goes southward winter wheat becomes possible and in the southern part of the central zone two crops a year are the regular order of things, wheat in winter and rice in summer, therefore a Central Zone between 32° F. and 40° F. can be defined. The south of Japan is semitropical, and as many as three crops a year are being raised; this may be termed the Southern Zone. Formosa, being tropical, stands by itself as the fourth climatic zone.

Variations in the rainfall due to the varying direction of the prevailing winds, and difference in the frequency of the cyclonic storms, make necessary certain subdivisions of the two northern of the agriculturist's zones. The Northern Zone may be divided into an extreme *northern division*, with Nemuro as its type, where the rainfall is scanty, and a southerly division with Hakodate as the type, where the rainfall is greater, and the variability, both in rainfall and temperature, is more *pronounced*. On the other hand, the Central Zone is divided by a north-south line, into an eastern region which gets summer rain, and a western region which gets winter rain. The other two zones of the agriculturist remain unchanged.

Fig. 17 shows the extent of these zones, and fig. 14 shows temperature and rainfall graphs of typical places in each.

1. *The Northern Zone.*—(*a*) The Nemuro type. In the extreme northern part, comprising the greater part of the island of Yezo, the climate is unusually severe for the latitude and unusually extreme for an island. The average winter temperature is everywhere below 20° F. and winter continues for more than three months, while in the center the average temperature is as low as 12° F. The severe winter is followed by a summer during which the average temperature is as high as 70° F. in the center, and is nowhere less than 60° F. Thus northern Yezo may be said to have a continental climate although it is a small piece of land entirely surrounded by water.

The extreme north differs from the rest of the Northern Zone in having a scanty rainfall; less than 20 inches annually falls throughout the greater part of this region. The map which shows the course of the cyclonic storms gives a clue to the reason for this scarcity of rain; since the storms sweep northward along two tracks, the larger branch passing over Tokyo and so eastward to the ocean, and the smaller branch passing over Niigata and northward to the Japanese Sea, neither branch sweeps over northern Yezo. As a result the rain is scarce and the variability of the climate of the extreme north is far less than in the center.

(*b*) The Hakodate type. As one travels toward the south both winter and summer temperature become less

[6] Outlines of Agriculture in Japan, Agricultural Bureau, Tokyo, 1910.

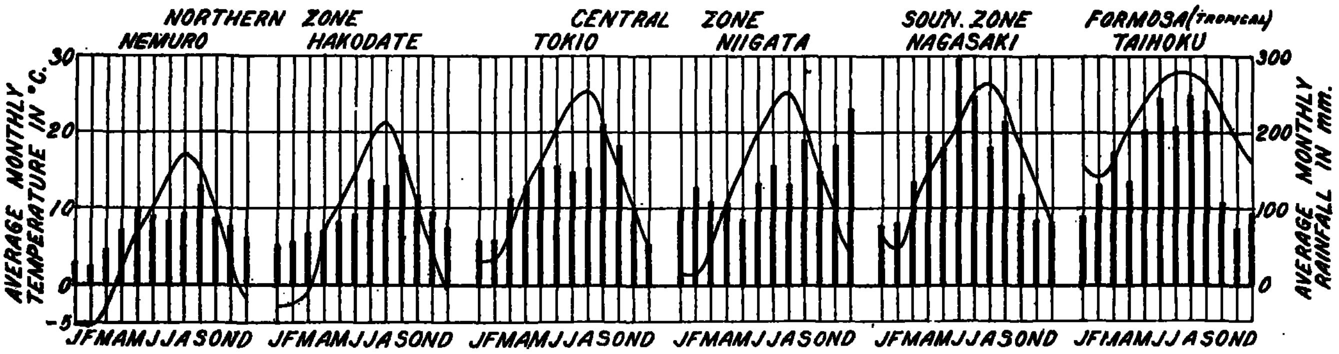

FIG. 14.—Average monthly temperature (solid lines) and rainfall curves (vertical bars) of typical places in each zone.

extreme, as is shown in figs. 5 and 7, and the rainfall increases, as is shown in figs. 12 and 14. More storms are received, as is shown in fig. 15, and this accounts both for the increase in the rainfall and for the greater variability of the climate.

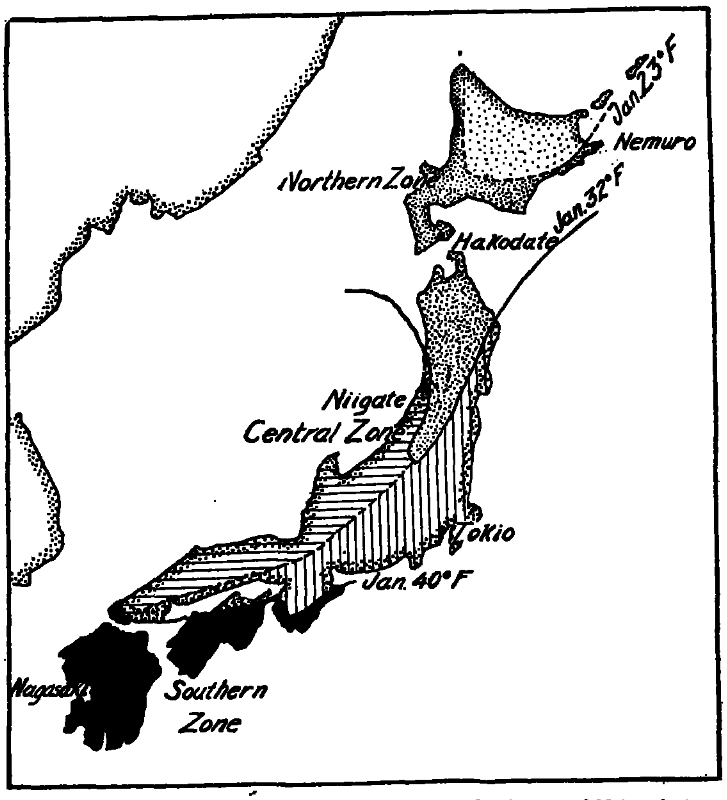

FIG. 17.—Map showing climatic zones. (Isotherms after Tokio Central Meteorological Observatory, Tokio.)

2. *The Central Zone.*—(*a*) The Tokyo type. This zone comes nearest to the optimum both in temperature and humidity (as defined by Prof. Huntington),[7] as well as being the most variable on account of the storms. It is interesting to note that this zone includes the most progressive part of Japan where manufactures are springing up, where trade is most vigorous, where the university is the oldest and most energetic, and where the seat of government is situated.

The central part of the eastern coastal strip of Japan is a good deal warmer in winter than corresponding regions on the opposite coast (fig. 7). This can perhaps be explained as the influence of the Kuroshio and the protecting backbone of mountains which shelter the coastal strip from the bitter winds from Siberia, and cause it to have fine clear weather during the greater part of the winter. It is, however, cold enough for snow to fall in all parts and to lie upon the ground even in the south. The relief is of the greatest assistance to the farmers since the sheltered slopes face southward and thus get greater insolation. The cyclonic storms are most frequent in this part (fig. 15) and account in part for the heavy summer rainfall, the noticeable dip in the rainfall graph during the summer months being due to the fact that the cyclonic storms are less frequent in July than in June or August.[8] Ranges of high mountains running parallel to the coast receive the full force of the prevailing winds from the ocean and cause this coastal strip to be one of the rainiest parts of Japan.

(*b*) The Niigata type. The western coastal region does not differ greatly in temperature from that of the eastern coast, but most people would find it a much less agreeable climate, since it gets far more rain and fog, and less bright sunshine. In winter, during the regular rainy season, not a day passes without some rain or snow brought by the bitter northwest winds, and in summer the cyclonic storms bring a good deal of rain, the same double maximum being noted as in the Tokyo graph.

3. *The Southern Zone.*—This zone is semitropical. Its average winter temperature is over 40° F. The climate is warmer than that of the Central Zone although snow falls in the winter and sometimes lies on the ground. Its average summer temperature is between 75° and 80° which is rendered enervating by its great humidity. The rainfall is very heavy, being over 80 inches a year north coast, the greater part comes in summer. Cyclonic storms are numerous and the variability, though less than the Tokyo type, is still considerable, so that its climate is far more stimulating than that of Formosa.

4. *Formosa.*[9]—Formosa is situated on the Tropic of Cancer and has a tropical climate. The summers are long and are accompanied by intense heat. The transition from summer to winter is very rapid, the warm season coming quickly after the cold months. The winters are short and no severe cold is known although high mountain peaks are snow capped; frost, as a rule, is unknown on the lower levels.

In Formosa the year is divided into two seasons; summer from April to October and winter from November to March.

The mean monthly temperature of January is in the coolest parts over 60° F. June to September is the hottest part of the year, the mean monthly temperature ranging between 79° and 82° F. No marked variation between north and south is seen during these months. The daily maximum will often rise above 86° F. and continue so for a whole month. Sometimes the east

[7] World Power and Evolution, Ellsworth Huntington, New Haven, 1919, pp. 58-104.

[8] Atlas of Meteorology, plate 28.

[9] The Climate, Typhoons and Earthquakes of Formosa, Taihoku Meteorological Observatory, Taihoku, Formosa, 1914.

coast near the border experiences a hot, dry wind similar to the foehn, which raises the temperature considerably.

In winter the north differs somewhat from the south. February is the coldest month, with 68° F. average monthly temperature in the south, and 57° F. in the north.

WIND AND RAIN.

During the winter a strong northeast monsoon blows steadily and this, combined with the mountains, causes heavy rainfall in the north, which lasts for several months. Kashoryo on the hillside near the eastern coast is probably the wettest place in the Far East, having an average rainfall of 7,338 mm. (289 in.). The west coast gets less rain because it is protected by the mountains.

During the summer the southwestern monsoon prevails, and except during the occurrence of a typhoon the winds are light. Frequent thunderstorms give abundant rainfall, and a typhoon will bring several hundred mm. of rain on a single day.

Formosa lies in the highway of the great storms known as typhoons. These storms originate in the sea surrounded by the Philippines, the west Carolines, and the Mariana Islands, or else in the China Sea itself.

The earliest typhoons that visit Formosa occur in May and the latest in November, and sometimes from December to April there are none. August is the month when they generally occur, and their frequency may be judged from the fact that in the 17 years from 1897 to 1913 there were 30 remarkably severe typhoons; 15 of these occurred in August.

The storms move generally toward the northwest or west-northwest, and the northern half of the island of Formosa is directly in that district. The force of the wind is terrific, and there is generally a corresponding ocean swell which is felt on the southwest coast.

Fig. 13 (Chart XV) epitomizes the characteristics of the climate of Formosa.

Average monthly temperature in °C.

(1) Northern zone.			(2) Central zone.			(3) Southern zone. (4) Formosa (tropical zone)		
	Nemuro.	Hakodate.		Tokio.	Niigata.		(3) Nagasaki.	(4) Taikoku.
Jan.	−5.1	−3.1	Jan.	3.0	1.5	Jan.	6.0	15.7
Feb.	−5.5	−2.6	Feb.	3.5	1.2	Feb.	4.4	14.0
Mar.	−2.5	0.7	Mar.	6.8	4.5	Mar.	9.2	16.9
Apr.	3.0	6.4	Apr.	12.6	10.4	Apr.	14.4	20.7
May.	6.6	10.4	May.	16.5	15.0	May.	17.9	23.8
June.	9.8	14.2	June.	20.4	19.3	June.	21.6	26.6
July.	14.1	18.5	July.	23.8	23.5	July.	25.5	27.9
Aug.	17.2	21.3	Aug.	25.4	25.5	Aug.	26.6	27.7
Sept.	15.1	17.4	Sept.	21.8	21.3	Sept.	23.4	26.2
Oct.	10.4	11.4	Oct.	15.8	15.1	Oct.	18.8	23.3
Nov.	4.3	5.3	Nov.	10.3	9.4	Nov.	12.8	19.6
Dec.	−1.4	−0.3	Dec.	5.3	4.1	Dec.	7.9	16.7
No. of years of observation.	33	40	No. of years of observation.	37	31	No. of years of observation.	34	18

Average monthly rainfall in mm.

(1) Northern zone.			(2) Central zone.			(3) Southern zone. (4) Formosa (tropical zone).		
	Nemuro.	Hakodate.		Tokio.	Niigata.		(3) Nagasaki.	(4) Taikoku.
Jan.	28.5	55.8	Jan.	57.1	96.3	Jan.	78.9	91.0
Feb.	21.1	57.7	Feb.	58.0	125.2	Feb.	81.7	130.7
Mar.	43.7	64.1	Mar.	109.2	104.6	Mar.	130.1	175.8
Apr.	70.2	69.3	Apr.	131.8	106.0	Apr.	196.6	137.6
May.	97.7	80.1	May.	156.9	82.8	May.	180.1	204.9
June.	90.6	89.9	June.	153.8	132.9	June.	294.9	241.2
July.	85.9	138.0	July.	143.3	156.9	July.	245.3	207.0
Aug.	94.0	129.3	Aug.	145.2	130.9	Aug.	177.5	246.9
Sept.	134.5	168.4	Sept.	210.6	186.6	Sept.	210.9	233.2
Oct.	88.1	114.3	Oct.	180.1	146.3	Oct.	117.6	102.7
Nov.	79.2	95.8	Nov.	100.3	182.5	Nov.	85.4	72.6
Dec.	62.0	79.3	Dec.	54.1	232.6	Dec.	85.4	93.1
Total.	825.7	1,142.0	Total.	1,500.4	1,793.5	Total.	1,884.4	1,940.1

HISTORICAL NOTE ON CHARTS OF THE DISTRIBUTION OF TEMPERATURE, PRESSURE, AND WINDS OVER THE SURFACE OF THE EARTH.

The state of the atmosphere at any given point is completely determined when we have given the values at that point of the six *meteorological elements*—temperature, pressure, wind, humidity, cloud, and precipitation (electrical state has no influence on the phenomena we are considering). The day to day fluctuations of these elements, caused by disturbances in the atmosphere, constitute *weather*, whereas the "normal" values, obtained by averaging a very long series of observations in order to eliminate the chance irregularities, largely characterize the *climate*. The varying climate found at different localities over a wide area is most conveniently represented graphically by means of isometric charts.

For purposes of theoretical and dynamical meteorology, it is essential to have such charts for the entire globe, without, however, going into any minute climatological details. "Normal" values have but little significance or utility for practical meteorology, other than descriptive climatology, as pointed out, *e. g.*, by J. Rouch, *Préparations Météorologiques pour les Voyages Aériens*, Paris, 1920.

Meteorological phenomena are all due to the flood of energy received from the sun; hence the measurement of the amount of *solar radiation*, and the distribution of *insolation* over the surface of the earth and throughout time, become of fundamental importance as subjects of investigation.[1]

The primary meteorological phenomenon to which insolation gives rise—temperature, and its diurnal and annual variations—must be assigned first place in the chain of cause and effect in meteorology; were the sun blotted out of existence, a lifeless uniformity would take possession of the earth; were the distribution of temperature over the earth always the same and the temperature uniform, a calm equilibrium would ensue.[2] The temperature, pressure, and prevailing winds, because of their intimate relations with one another, are best dealt with together; taken in conjunction with the topography, etc., they determine the distribution of the remaining elements, and the climatological characteristics of any region.

[1] *Cf.* C. Dorno, On Observations of Solar and Sky Radiations and Their Importance to Climatology and Biology and also to Geophysics and Astronomy, MONTHLY WEATHER REVIEW, 48, 18–24, 1920; J. B. Kincer, Sunshine in the United States, MONTHLY WEATHER REVIEW, 48, 12-17, 1920; H. H. Kimball, Variations in the total and luminous Solar Radiation with Geographical position in the United States, MONTHLY WEATHER REVIEW, 47, 769–793, 1919; *Annals of the Astrophysical Observatory of the Smithsonian Institution*, vols. 1–3.

[2] Laplace, *Méc. Cél.*, Bk. 1, Art. 37; Bk. 3, chap. vii. Ferrel, *Rept. U. S. Coast Survey*, 1875, p. 402; W. J. Humphreys, *Physics of the Air*, chap. vii.